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Morphophysiological characteristics of upland rice plants with organic approach through reduced NPK fertilizer and wood vinegar application

Abstract. Unefficient use of synthetic fertilizer in upland rice production leads to the low productivity and tends to harm the environtment. An organic approach by using wood vinegar is promising to improve the fertilizer efficiency. The objective of this study was to determine the response of upland rice with the application of different wood vinegar and synthetic fertilizer N-P-K rates on morpho-physiological characters. A split plot design with the main plot of N-P-K fertilizer and a subplot of wood vinegar was applied with three replications. Growth and physiological character were observed. The data were analyzed by the F test, then proceed with the Duncan Multiple Range Test at $p \leq 0.05$. The results showed that a half and full recommended synthetic fertilizer rate of N-P-K had a similar result to gaining optimum morpho-physiological character of upland rice. Wood vinegar with a rate of 75 L ha^{-1} obtained the highest performance on morpho-physiological character of upland rice. An increasing application rate of wood vinegar improved the morpho-physiological character of upland rice at different rates of N-P-K synthetic fertilizers.

Keywords: Morpho-physiological characters · N-P-K fertilizers · Upland rice · Wood vinegar

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Introduction

Rice is one of the most important crops in the world, especially in Asia countries including Indonesia. Nutrient management is a key entry point to maintain physiological mechanisms in contributing to optimum plant growth and development. Three major essential plant nutrients, N-P-K as the primary macronutrients because of the large quantities taken up by plants from the soil relative to other essential nutrients (Nurmala et al., 2015). Deficiency in these nutrients inhibits plant growth and development. The elements of N-P-K play an important role in plant growth and physiological processes and yield as well (Liu et al., 2014).

Fertilization must be applied as the plant needs to maintain the ability of soil to provide nutrients and survival of microorganisms (Sabry, 2015). Meanwhile, the application of synthetic fertilizer of N-P-K inadequate crop demand (Wahyudin et al., 2017). Consequently, the supply of nutrients is often insufficient to meet crop demands and over rates. This condition hampers plant physiological processes to gain optimum growth. Therefore, there is a need to explore the efficient utilization of the available nutrient resources that lead to improved plant growth by a combination of synthetic fertilizers with potential organic matter.

Farmyard manure, crop residues, and composts for a short-term supply of nutrients and long-term build-up of soil organic matter are commonly used. But, the application of these organic matter does not affect making balancing with the application of synthetic fertilizer. Wang et al., (2016) mentioned that the application of organic materials can be used as an alternative to reducing the use of synthetic fertilizers and able to maintain environmental balance. Therefore, finding the potential organic matter to reduce the application of synthetic fertilizer and improve plant growth must be explored.

The environment friendliness and renewability resource by using biomass is considered through converted to liquid fuels such as wood vinegar by the thermochemical approaches to obtain high value-added products (Lu et al., 2019). Wood vinegar as a source of organic matter needs to explore. Wood vinegar increases the activity of antioxidant enzymes, guaiacol peroxidase, and ascorbate peroxidase accelerated amylase activity (Dissatian et al., 2018).

Therefore, it increases root activity, which promoted the seed germination and root growth (Lu et al., 2019; Robb & Joseph, 2019), and reduce insects attack and bacterial diseases (Rogelio, 2018), fungal diseases and improve both plant health and crop quality (Robb & Joseph, 2019). Rogelio (2018) mentioned that 1% dilution of wood vinegar improves the growth and yield of rice. Anotherr study revealed that using wood vinegar about 2 mL L^{-1} by foliar application improves crop yield, but as fungicide at a rate of equal parts vinegar to water is required (Robb & Joseph, 2019).

Wood vinegar application achieves rapid and uniform seed germination in upland rice (Dissatian et al., 2018) and generally improves seed germination (Robb and Joseph, 2019). Few studies were done to explore the capacity of wood vinegar on upland rice. Contribution of this study could be a benefit to improve the performance of upland rice in dryland areas especially in tropical countries by using natural resources and environmentally friendly and reduce the application of synthetic fertilizers. Wood vinegar has benefit to further utilization as a sustainable alternative to chemicals for plant growth regulation in agriculture (Lu et al., 2019) and no harm to any beneficial insects and reduce chemical pesticide (Robb & Joseph, 2019).

Therefore, this study needs to be conducted to find out the influence of wood vinegar and N-P-K fertilizer on plant growth and physiological characters of upland rice in dry land area and to investigate the low dosage application of synthetic fertilizers to support physiological process and plant growth.

Materials and Methods

Field site. The study was conducted during one planting season during the dry season in April-July 2017 at Experimental Farm, Klampok District, Banjarnegara Regency, Central Java, Indonesia, with a coordinate of latitude of 7°27′ N, longitude of 109° 28′ E and altitude of 85 m above sea levels). The rainfall intensity, relative humidity, and temperature were 80 mm, 75%, and 30 ^{0}C, respectively, on average during the study. The soil of the experimental site at 0-30 cm depth had a soil texture of sandy loam, pH (Potentiometry) of 6, organic matter content (Walkley and Black) of 5.17%, total nitrogen (N) (Kjeldahl) of 0.17%, available phosphorous (P) (Bray I) of 5.36 mg kg^{-1}, extractable potassium (K) (Bray I) of 145.41 mg kg^{-1} and Cation Exchange Capacity (*N* NH_4OAc pH 7.0) of 15.42 $cmol^{(+)}$ kg^{-1}.

Experimental materials and treatment. Upland rice seeds of Inpago Unsoed 1 variety, fertilizers i.e. urea, SP-36, KCl, and wood vinegar were applied. Split plot design with the main plot of rate of N-P-K fertilizer according to the recommended rate of 100 N, 100 P205 and 50 K2O kg ha-1 i.e. a half and full recommended rates and subplot of the rate of wood vinegar (WV) i.e. 0, 4.686, 9.375, 18.75, 37.50 and 75.00 L ha-1 were applied with three replication. At sowing time, the full rate of P2O5 and K2O and one-third rate of N were applied according to treatment. Two-third rate of N was applied at tillering and panicle initiation stages. Each plot size of 2.0 m x 4.0 m and distances 0.5 m between plots with 1.0 m between blocks were arranged.

Observed Variables. Observed variables viz. growth character, i.e. number of leaves, leaf area (cm^2), plant height (cm), number of tillers, shoot dry weight (g) and root dry weight (g), and physiological characters viz. proline content (µmol g^{-1}) (Bates et al., 1973), chlorophyll a and b (mg g^{-1}) (Yoshida et al., 1976) were observed at the end of the vegetative stage.

Statistical Analysis. The observed data were analyzed by the F test to find out the significance level of each treatment and its interaction on observed variables. If there were significant differences, then proceed with the Duncan Multiple Range Test (DMRT) at $p \leq 0.05$. Both analyses were applied using the statistical program CropStat 7.2 (IRRI, 2007).

Results and Discussion

Generally, applications of N-P-K fertilizer and wood vinegar in different rates have been shown the various effect on upland rice performance. A half rate of N-P-K fertilizers resulted in an equal to the full recommended rate on all morphological and physiological characters. But, the application of wood vinegar resulted mostly to improve the performance of upland rice.

Morphological Character. Rate of different N-P-K fertilizers gave no significant effect on all morphological characters of upland rice. Application N-P-K fertilizers of a half and full recommended rates was not significantly different on plant height, leaf area, the total number of tillers and, shoot and root dry weights in the range of 69.11-69.94 cm, 39.23-41.52 cm^2, 29.41-31.09 g, 22.40-22.56, and 3.79-6.06 g, respectively (Table 01.). The similar results indicated with an increase in the N-P-K fertilizer rate was not affect significantly to improve growth performance.

Wood vinegar with a rate of 75 L ha^{-1} with the highest value found in all growth characters of plant height, leaf area, the total number of tillers and, shoot and root dry weights. The increases of all components of growth were affected by the application of wood vinegar, with an increase on plant height with rate from 68 cm for no application (0 L ha^{-1}) to approximately 72 cm for the maximum application (75 L ha^{-1}). The similar results no application (0 L ha^{-1}) and a high rate (75 L ha^{-1}) of wood vinegar obtained on leaf area, the total number of tillers and, shoot and root dry weights i.e. 39 and 43 cm^2, 20 and 25, 25 and 38 g and, 3 and 4 g, respectively (Table 1).

Table 1. Plant growth characters of upland rice with application of N-P-K fertilizers and wood vinegar.

	Plant height (cm)	Number of leaf	Leaf area (cm^2)	Number of Tiller	Dry shoot weight (g)	Dry root weight (g)
N-P-K recommended (kg ha^{-1})						
50% rate	69.94	24.38	41.52	22.40	29.41	3.79
100% rate	69.11	24.31	39.23	22.56	31.09	4.06
WV (L ha^{-1})						
0	68.16 d	25.43	39.06 d	20.67 e	25.90 e	3.43 e
4.686	67.33 d	26.50	39.51 cd	20.67 e	27.27 d	3.62 d
9.375	69.03 c	23.97	39.60 c	21.60 d	28.47 c	3.80 c
18.75	69.40 c	23.60	39.74 c	22.73 c	30.13 b	3.88 c
37.50	70.42 b	22.20	40.88 b	23.70 b	30.77 b	4.20 b
75.00	72.80 a	24.37	43.46 a	25.50 a	38.96 a	4.63 a
CV (%)	3.18	13.03	2.91	5.76	8.29	5.91

Note: recommended rate of N-P-K was 100 N, 100 $P_2 0_5$ and 50 K_2O kg ha^{-1}, respectively, WV=wood vinegar, CV=coefficient variance. In the same column, the number followed by the same letter indicates no significant difference according to the DMRT at $p \leq 0.05$.

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Table 2. Physiological characters of upland rice with application of N-P-K fertilizers and wood vinegar.

	Proline content (µMol g^{-1})	Chlorophyll content (mg g^{-1})	
		Ch a	Ch b
N-P-K recommended (kg ha^{-1})			
50%rate	14.05	3.65	1.53
100% rate	14.58	4.01	1.73
WV rate (L ha^{-1})			
0	12.41	3.65	1.39 c
4.686	14.78	3.94	1.48 c
9.375	12.97	3.35	1.34 c
18.75	10.07	3.76	1.52 c
37.50	10.53	3.88	1.87 b
75.00	13.43	4.40	2.25 a
CV (%)	23.00	10.90	11.44

Note: recommended rate of N-P-K was 100 N, 100 P_20_5 and 50 K_2O kg ha^{-1}, respectively, WV=wood vinegar, CV=coefficient variance. In the same column, the number followed by the same letter indicates no significant difference according to the DMRT at $p \leq 0.05$.

Generally, there were significant differences in all morphological characters between no application and application of wood vinegar. Thus, an increase in the rate of wood vinegar up to 75 L ha^{-1} rate gained the high performance of upland rice growth.

Physiological Character. The application of different N-P-K fertilizer rates gave no significant effect on all physiological components of upland rice. The results obtained in the treatment of a half and full recommended rates on proline content of 14.05-14.58 µMol g^{-1}, Meanwhile, chlorophyll a and chlorophyll b about 3.65-4.01 mg g^{-1} and 1.53-1.73 mg g^{-1}, respectively (Table 2). Addition rate of N-P-K fertilizer could not improve proline content, chlorophyll a and chlorophyll b. Therefore, the low rate of a half N-P-K fertilizer affected to obtain the optimal physiological performance.

The results indicated a strong relationship between wood vinegar and chlorophyll b content. The maximum rate (75.00 L ha^{-1}) showed the highest chlorophyll b content of 2.25 mg g^{-1}. The application of wood vinegar in rate 9.375-18.75 L ha^{-1} produced no significant effect on chlorophyll b content in the range 1.34-1.52 mg g^{-1} and no significantly different with no application (0 L ha^{-1}) about 1.39 mg g^{-1} (Table 2). Chlorophyll b content tended to increase with an increase in the wood vinegar rate. The contents of proline and chlorophyll-a were not significant due to the application of wood vinegar with a range of 10.07-14.78 µMol g^{-1} and 3.35-4.40 mg g^{-1}, respectively (Table 2).

Discussion

The application of a half N-P-K rate indicated similar to the full N-P-K rate on all morpho-physiological characters (Table 1, 2). This provides information that the soil condition used as a planting medium in this study was able to support plant growth performance due to the application of 50% and 100% recommended dose of N-P-K fertilizers were able to produce equal growth and physiological characters (Table 1, 2). The availability of nutrients for plants is important and it can be fulfilled by the application of synthetic fertilizer (N-P-K) and it will affect the physiology process of plants. The major element of N-P-K plays an important role to support the metabolism process in plants (Ebrahimi et al., 2012; Pavlovic et al., 2014; Haque & Haque, 2016). The results of this study were matched with the expectation that N-P-K fertilizer applications can be reduced to 50% of the recommended rate to support a more environmentally-friendly agricultural system. Excessive application of fertilizers causes soil degradation physically, chemically, and biologically so that it will adversely plant growth and development. Yousaf et al., (2017) mentioned that over-fertilization can create salt concentration by which directly impact on beneficial soil microorganism and insufficient root system to supply adequate water and nutrients to the plant.

In the present study, the high rate of N-P-K fertilizers (recommended rate) could not improve plant height, leaf area, number of tillers, dry shoot, and root weights (Table 1). Moreover, proline

content as plant stress indicator unaffected by high (full N-P-K) and low (a half N-P-K) rates and contents of chlorophyll a and b as well (Table 2). Therefore, the application of a half N-P-K rate did not give an adverse effect on plant growth but the plant could absorb the low availability of nutrients to generate chlorophyll in supporting optimum plant growth. Tardieu (2013) mentioned that sufficient absorption of nutrients increases the rates of photosynthesis and carbohydrate formation by which support the growth of plant organs especially shoots, roots, and leaves so directly increase biomass fresh weight. Therefore, the efficiency of synthetic fertilizer of N-P-K rose to support plant growth and physiological process in upland rice. Thus, soil conditions with high C organic (5.17%) and pH at 6.0 gave a positive effect on plant performance due to improvements sufficient of nutrient uptake by plants. Soil pH and organic matter strongly affect soil functions and plant nutrient availability. Moreover, pH influences the solubility and availability of plant nutrients and organic matter decomposition (Adak et al., 2014).

Different response happened to physiological characters. Proline and chlorophyll a content had similar responses due to the application of wood vinegar. The proper response was gained on chlorophyll b content only at a different rate of wood vinegar (Table 2). Increased rate of wood vinegar improved the content of chlorophyll b. The wood vinegar showed an overall higher chlorophyll content compared to the no application of wood vinegar. The function of photosynthetic activity is monitored based on fluorescence and absorption of light re-emitted or released by plant leaves such as quantification of chlorophyll (Pavlovic et al., 2014). In this case revealed that chlorophyll b had higher response than chlorophyll a due to the higher content in plant leaves.

Wood vinegar had a strong relationship with plant growth characters. The maximum rate (75.00 L ha^{-1}) of wood vinegar exhibited the highest plant performance compared to other rates. An increasing rate of wood vinegar obtained greater plant height, leaf area, number of tillers, dry shoot, and root weights (Table 1). The increase in vegetative growth is followed by an increase in chlorophyll levels. Negi et al. (2017) stated that the formation and acceleration of plant growth in stimulating plant vegetative organs such as root and leaf growths due to the high content of chlorophyll.

An increase in the rate of wood vinegar and the rate of N-P-K fertilizers did not increase the number of leaves. This indicated the availability of wood vinegar improved N-P-K fertilizer efficiency. Increased efficiency in the use of N-P-K fertilizer is influenced by the presence of acetic acid in the wood vinegar. Wood vinegar contains some organic acids such as acetic acid (Mela et al., 2013). Acetic acid is a precursor from the auxin hormone and as well-known that auxin has some functions such as apical dominance and differentiation and root branching.

Currently, awareness of environmental safety is enhanced, which is globally acknowledged for reduced levels of chemical residues. The agricultural system through organic farming is a method to avoid or largely exclude the use of synthetic input such as fertilizers and instead relies on crop residue. Thus, accelerate to develop organic rice farming is important over and done with applying organic cultivation techniques. This study was revealed that the application of wood vinegar could improve morpho-physiological characters of upland rice. Therefore, the low rate of N-P-K fertilizers with the availability of wood vinegar had a chance to produce a suitable performance of upland rice and it could improve growth performance in other crops. However, the further exploration of both treatments still needs to carry out for resulting the deeply scientific information.

Conclusion

The applications of N-P-K fertilizers a half and full recommended rates had the same impact on morpho-physiological characters but it improved due to the application of wood vinegar at a rate of 5%. Reduction of 50% N-P-K fertilizers along with the increasing rate of wood vinegar improved morpho-physiological characters of upland rice. Due to different dose of N-P-K fertilizer was no effect on morpho-physiological characters. Therefore, the application of wood vinegar could reduce the synthetic fertilizer dose to improve upland rice in environmental friendly production.

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